Commonality and Heterogeneity in Real Effective Exchange Rates: Evidence from Advanced and Developing Countries

Nagayasu, Jun

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Jun Nagayasu‡

Abstract

In order to differentiate between commonality and heterogeneity in real effective exchange rates, which are considered a measure of external competitiveness, we decompose their movements into global and country-specific factors using the Bayesian factor model. First, we show a complex but often positive relationship between real exchange rates and net trade volume using panel data of developed and developing countries. Then we report a particular global trend in real exchange rates, but a substantial proportion of their variation is found to be country-specific. In line with this finding, we conclude that structural shifts, when they do exist, are considered country-specific factors. Furthermore, consistent with economic theory, this global factor is closely related to a trend in the global interest rate, while country-specific factors are closely related to idiosyncratic movements in the countries' own interest rates. Such a decomposition results in better model performance in terms of coefficient signs, and therefore our results suggest that external competitiveness is heterogeneous among countries and that economic policy can influence countries competitiveness.

Keywords: Real effective exchange rates, factor model, variance decomposition, external competitiveness
JEL classification: F31

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‡University of Tohoku, Graduate School of Economics and Management, Address: 27-1 Kawauchi, Aoba-ku, Sendai, Miyagi 980-8576 JAPAN, Email: jnagayasu@econ.tohoku.ac.jp, Tel: +81 22 795 6265, Fax: +81 22 795 6270

1 Introduction

Co-movements in exchange rates have been analysed in several contexts. Co-movements, which can be measured by the sensitivity of one currency to another in regression analysis or by the simple correlation coefficient, are important since changes in one currency indeed often affect the currency of other countries (e.g. McKinnon and Schnabl (2003)), particularly those with a flexible exchange rate regime. Furthermore, currency interdependence has been examined in the context of inferring actual exchange rate regimes which may be deviating from officially announced ones (e.g. Frankel and Wei (2008)).

Co-movements in exchange rates are also underlined during financial crises; deterioration in one's currency value almost simultaneously affects others through, for example, speculative attacks (e.g. Gerlach and Smets (1995), Masson (1998)). Such an effect is often called contagion in the academic literature and has become increasingly prominent in recent years when a series of financial crises affected the world economy. Such crises include the 1997 Asian crisis which erupted in Thailand, the Lehman Shock (2008) in the United States, and the European sovereign debt crisis which started in Greece (2009). Each crisis led the original country's economy and the regional and/or world economy into recession.

The majority of previous studies on co-movements seem to have investigated commonality in stock prices; furthermore, those on foreign exchange markets have focused largely on bilateral nominal exchange rates (see the abovementioned literature and the next section). However, foreign exchange transactions are conducted in a global context with the involvement of more than two countries. Furthermore, researchers and policymakers are certainly interested in studying real effective exchange rates which are often regarded as an economic variable for measuring the external competitiveness of countries (e.g. UNCTAD (2012), Brixiova (2013)), and are considered, at least on theoretical grounds, as one important factor contributing to economic growth. Indeed, a number of empirical research projects have been conducted in order to investigate whether undervalued currencies bring about economic growth (e.g. Bhalla (2008), Rodrik (2008), Mbaye (2012), UNCTAD (2012), Brixiova (2013), Levy-Yeyati et al. (2013)).[1]

[1]While there is no consensus among previous empirical studies, some have confirmed a link between economic growth and real exchange rates through the trade channel (Bhalla (2008), Rodrik (2008)) and the productivity channel (Mbaye (2013)). Also see for example Orszaghova et al. (2013) about the

Against this background, this study analyses and quantifies co-movements in real effective exchange rates for a wide range of countries. There must be some level of correlation in these rates as they are affected by developments in international economies. However given that competitive and non-competitive countries co-exist in the global market, it would be of interest to researchers and policymakers to quantify the level of the rates' co-movements and determinants. We analyse the determinants based on previous studies which, without data decomposition, have used real interest rates to explain bilateral real exchange rates. Early studies tend to cast doubt on the credibility of this relationship for individual exchange rates (Edison and Pauls (1993), Edison and Melick (1999)), for example, based on the lack of cointegration and/or the wrong coefficient signs for real interest rates. However, stronger evidence in favor of this relationship has been reported by more recent studies (MacDonald and Nagayasu (2000), Byrne and Nagayasu (2010)) in the panel data context.

A distinguishing feature of this study is that real effective exchange rates are decomposed for a more comprehensive number of countries into global and country-specific factors using a Bayesian factor model. (The number of countries under investigation in previous studies seems often rather limited i.e., fewer than 15 countries, as summarised in Section 4.) The Bayesian model allows us to estimate a more comprehensive definition of global movements.[2] The decomposition into global and country-specific factors is also conducted for the driving forces of exchange rates. By doing so, we can estimate 'foreign' variables which are often assumed to be the U.S. data in previous studies. In this way, our statistical model departs from those of previous studies on bilateral exchange rates and becomes more congruent with economic theory and data.[3]

definition of external competitiveness.

[2]However, over the last decade much progress has been made in estimating commonalities in large data sets, especially studies on business cycles (Forni et al. (2000), Kose et al. (2003), Foerster et al. (2011)) and general commodity (non-financial asset) inflation (Bernanke et al. (2005), Canova and Ciccarelli (2009), Mumtaz and Surico (2012))

[3]Thus unlike contagion studies, this study does not emphasize the direction of causality from one country to another.

2 Driving forces behind real effective exchange rates

What are the driving forces behind real effective exchange rates? Among others, economic theory suggests that real exchange rates are determined by the real interest rate differential or the productivity differential in tradable sectors (known as the Balassa-Samuelson theorem). Here we use real interest rates which are available for more countries, and summarise their theoretical link, following Obstfeld and Rogoff (1996). Their derivation of the model is more general than the conventional one using solely the purchasing power parity (PPP) theorem and the uncovered interest rate parity (UIRP) condition, in the sense that sticky prices are considered in the model.

Let us consider domestic inflation which can be explained by the Dornbusch-type inflation specification for an open economy:

$$\Delta p_{t+1} = \gamma(y_t^d - \overline{y}_t) + \Delta s_{t+1} + \Delta \tilde{p}_{t+1}^* \tag{1}$$

where y_t^d is the demand for home country output, s is the nominal effective exchange rate and p is the price. All variables are in log form, and Δ represents the differenced operator; therefore, $\Delta p_{t+1} = p_{t+1} - p_t$ becomes inflation. A variable with a bar indicates a natural level, and a foreign variable is denoted with an asterisk. In the presence of multiple partner countries, the latter can be thought of as a weighted average of foreign variables suggested by the tilde in Eq. (1). The $\gamma > 0$ implies that home inflation increases due to excessive demand for home products, exchange rate depreciation, and increases in foreign inflation. In such cases, there is no market clearance, that is, $\Delta p_{t+1} \neq 0$.

Further, the demand for home products (y_t^d) is assumed to be expressed as:

$$y_t^d = \bar{y}_t + \delta(s_t - p_t + \tilde{p}_t^* - \bar{q}) \tag{2}$$

where $\delta > 0$. As in the previous studies, the long-run (or natural) real exchange rate ($\bar{q}$) is assumed to be fixed here. According to Eq. (2), the demand for domestic goods exceeds its natural level to an extent proportional to the level of currency misalignment.

Using the definition of the real exchange rate ($q_t \equiv s_t - p_t + \tilde{p}_t^*$) which suggests that gains in external competitiveness are shown as increases in q_t, and the UIRP ($\Delta s_{t+1} = i_t - \tilde{i}_t^*$ where i_t is the nominal interest rate), Eqs. (1) and (2) yield

$$\Delta p_{t+1} = \gamma\delta(q_t - \bar{q}) + i_t - \tilde{i}_t^* + \Delta\tilde{p}_{t+1}^* \tag{3}$$

In addition, using the Fisher condition ($i_t = R_t + \Delta p_{t+1}^e$ where R_t is the real interest rate and a variable with superscript e indicates an expected value) and rearranging Eq. (3) in term of the real exchange rate, we can obtain the following relationship:

$$q_t = \bar{q}_t - \frac{1}{\delta\gamma}(R_t - \tilde{R}_t^*) \tag{4}$$

Since γ and δ are theoretically positive, this equation asserts that there would be home currency depreciation when the real interest rate falls at home. Eq. (4) is an appropriate theoretical framework even when a country is confronted with very low nominal interest rates since real interest rates can be negative owing to the presence of expected inflation. However, as mentioned, previous studies (e.g. Edison and Pauls (1993)) often report wrong parameter signs for real interest rates. For the estimation, we consider the equation of exchange rate changes which is consistent with an a priori assumption of the standard factor model:

$$\Delta q_t = -\frac{1}{\delta\gamma}\Delta R_t + \frac{1}{\delta\gamma}\Delta\tilde{R}_t^* \tag{5}$$

We base our empirical analysis on Eq. (5): since there are two components (global and country-specific factors) in real effective exchange rates, each factor is estimated by real interest rates. The global factor in real effective exchange rates is expected to be determined by the global interest rate ($\tilde{R}_t^*$), and the country-specific factor by idiosyncratic movements in the interest rates (R_t).

3 Data and preliminary analyses

Real effective exchange rate (Q) data are obtained from the International Financial Statistics (IFS) of the International Monetary Fund. They (IFS code: ..REUZF, 2005 = 100) are constructed using the consumer price indices (CPI) and weights determined by the size of trade (unit values) to each trading partner, and cover the sample period from 1980Q1 to 2014Q3 for 78 countries, including both advanced and developing economies (see Table 1). The country coverage and the sample period are determined by data availability from the IFS and maximise the total number of observations.[4] In the subsequent analysis, we analyse exchange rate growth, that is, the first difference of log exchange rates ($\ln(Q_t/Q_{t-1})$), in order to be congruent with an a priori assumption of the data required for the factor model.

The basic statistics of the exchange rates are summarised in Table 2. The sign of the average (ave) exchange rates suggests that the direction of exchange rate movements is diversified, and almost three-quarters (72 percent) of the countries have experienced a fall in exchange rates (Table 2). Furthermore, developing countries have experienced a higher level of exchange rate volatility than advanced countries, measured by the standard deviation (std. dev.). This outcome seems to be closely associated with the deterioration in domestic economies; for example, Poland was confronted with accelerating inflation from the late 1980s to the early 1990s.

Table 1 also provides information about the data required to calculate real interest rates, which we obtain on the basis of the Fisher hypothesis (real interest rates = nominal interest rates expected inflation rates). Here, nominal interest rates are either the market rates or deposit rates, and as a proxy for expected inflation we assume ex ante inflation using the CPI.[5] Data availability for the interest rate and CPI reduces the number of countries to 17, for which there are sufficient time-series data for statistical analysis; most of the countries are advanced countries.

The time-series properties of real exchange rates and interest rates are examined by panel unit root tests. In order to examine the null hypothesis of non-stationary data, we implement two types of tests, namely, the Levin-Lin-Chu (LLC, (2002)) and Fisher-type (Choi (2001)) tests. In order to take into account cross-sectional dependence, the LLC statistic is obtained by removing the cross-sectional mean from the original data prior to the test. The second test is based on the work of Fisher (1932) who proposed pooling p-values from independent tests in order to create a statistic which can be used to assess unit roots in the panel data context. Furthermore, following Choi (2001), different specifications of the latter test are used. Table 3 reports strong evidence of a stationary

[4]The other definition of real effective exchange rates is available from the IFS. However, the country coverage for the alternative rates is much narrower than that based on the CPI.

[5]The general conclusion remains the same even when ex post inflation is used.

process for changes in both real exchange rates and interest rates; the null is rejected at the one percent significance level in favor of the alternative of stationarity. Although our data are effective rates, the stationarity of differenced exchange rates is consistent with previous studies on bilateral exchange rates which have achieved the stationarity after taking the first difference (Hallwood and MacDonald (2000)).

While our analysis focuses on the real exchange rate-interest rate relationship, real exchange rates are often discussed as related to international trade at least in theory. Therefore, as part of our preliminary analyses, we calculate the correlation coefficients between real effective exchange rates and net trade volume.[6] Since their causality remains questionable (e.g. McKenzie (1999), Barkoulas et al. (2002)), we conduct this exercise for two cases where real exchange rates affect previous and future trade volumes (Table 4). Our statistical results show the complex nature of this relationship[7]: we discover a link between exchange rates and international trade, but the degree of statistical significance depends on the gestation periods (i.e. a lead or lag length) during which exchange rates (the trade balance) are thought to influence the trade balance (exchange rates). Notably, we often obtain evidence of the expected outcome, that is, a positive correlation between exchange rates and net trade volume, and in line with the conventional economic theory (e.g. the J-effect) there is a time lag (slightly more than one year) for them to influence one another statistically significantly. This shows why real effective exchange rates have often been considered a measure of external competitiveness.

4 Empirics

There are several statistical approaches to analyzing co-movements in data. The traditional, and probably most popular, approach is to use correlation measures between data. Increased correlation is regarded as evidence of increased cross-country linkages, and high correlation during tranquil times with minimal risk premia is also interpreted as evidence of high capital market integration. Such research can be carried out either by simply calculating correlation coefficients among financial data or estimating the exchange rate

[6]The trade data are also obtained from the IFS.

[7]See for example the work of Orszaghova et al. (2013), which shows that country-specific factors (e.g. type of export goods, trading partners, corruption, and bureaucratic efficiency) affect the external competitiveness of EU candidate countries.

equation of one country with other countries' exchange rates as explanatory variables. Based on this approach, previous studies have pointed out unstable interrelationships and increased correlation at times of financial crises in equity markets (Longin and Solnik (1995), Reinhart and Carvo (1996), Liu et al. (1998), Bayoumi et al. (2007)). However, there are potential problems with this estimation approach. Obviously, the regression-based approach requires an exogeneity assumption about explanatory variables, but it may be difficult to justify this assumption using volatile financial asset data. Furthermore, Forbes and Rigobon (2002) argued that the standard regression analysis fails to take into account market volatility which differs during crisis and non-crisis periods.

Alternatively, co-movements can be estimated using a factor model or a principal components approach. The factor model is often used to distinguish between global and country-specific elements, and according to this approach, increases in the proportion of the global factor become evidence of higher cross-country linkages (Koedijk and Schotman (1989), Dungey (1999), Cayen et al. (2010)). The commonality in the data can also be estimated by the principal components approach. For example, Nellis (1982) analysed financial market integration using corporate and government bonds with the expectation that their yields will be dominated by common factors in a highly integrated financial market. Similarly, Volosovych (2013) studied financial market integration utilizing government bond yields from 1875 to 2009 and provided evidence of increased integration from the data through the end of the 20th century. However, the coverage of these studies is rather limited – often less than 15 countries – even when the factor/principal components approach is used.

This study follows the second strand of the literature (i.e., the factor model) in which all variables are treated as endogenous and which is thus more suitable for obtaining global factors from a large number of countries. We now explain the statistical method used to identify the number of common factors.

4.1 Identifying the number of common factors

Are there any common movements in real effective exchange rates and real interest rates? This section details our investigation, which involves identifying the number of common factors in these data using an advanced statistical method (Alessi et al. (2010)). While the factor model has been widely used in previous studies, the identification of the number of common factors has remained a big challenge for researchers.

The statistical approach of Alessi et al. (2010) is an extension to Bai and Ng (BN, (2002)), and thus is based on a factor model which for stationary data $(\mathbf{x}_{nt} = x_{1t}, ..., x_{nt})'$ is often expressed as:

$$\mathbf{x}_{nt} = \mathbf{\Lambda}_n \mathbf{F}_t + \mathbf{e}_{nt}, \quad \text{where} \quad t = 1, \ldots, T \tag{6}$$

where the data are standardized. $\mathbf{F}_t$ is a $k \times 1$ vector of common factors, and $\mathbf{\Lambda}_n$ is a corresponding factor loading matrix $(n \times k)$, where k $(k < \min(n, T))$ represents the number of common factors. Since the size of loadings can differ among n, $\mathbf{\Lambda}_n \mathbf{F}_t$ can be viewed as common elements which include heterogeneous responses of each country (n) to common movements $(\mathbf{F}_t)$. The residual $(\mathbf{e}_{nt})$ which cannot be explained by $\mathbf{F}$, is considered as idiosyncratic factors, and as in the standard model, common and idiosyncratic factors are assumed to be orthogonal. In our research setting, $\mathbf{x}$ becomes a vector of changes in real effective exchange rates or real interest rates.

While there are several statistical methods such as the Scree Plot to decide the appropriate number of common factors, recently a number of information criterion-type (IC) methods have been proposed by BN (2001). However, while BN provides several forms of penalty functions, the numerical simulations suggest that their estimation criteria tend to under- or over-estimate the true number of common factors (Alessi et al. (2010)). Thus we use a statistical method introduced by Alessi et al. (2010), who modified the BN criteria by introducing the extra term $(c \in \Re^+)$ to the penalty function.

$$IC(k) : \min_{0 \leq r^* \leq k} \quad ln(V(k, \hat{\mathbf{F}}^k)) + ckg(n, T) \tag{7}$$

where $V(.) = (nT)^{-1} \sum_{i=1}^{n} \sum_{t=1}^{T} (\mathbf{x}_{nt} - \mathbf{\Lambda}_n^k \mathbf{F}_t^k)^2$. A penalty factor $g(n, T)$ will make adjustments to the statistics for over-fitting in order to avoid cases where the solution is always equal to $k = n - 1$. More concretely, the large (small) c represents over-(under-) penalization, and when $c = 0$, it means no penalization. Furthermore, for a given k, the appropriate number of common factors (r^*) corresponds to minimisation of the sum of the residual squared and a penalty factor. Alessi et al. (2010) argued that c provides vital information about the number of common factors although this extra term does not affect the asymptotic performance in identifying the size of r^*. In that sense, their modification may seem trivial, but it has been shown to significantly influence the outcome with finite data (Alessi et al. (2010)).

Alessi et al. (2010) also argued that r^* should not be sensitive to the size of c. Thus once r^* is obtained, we shall check its stability by means of the S_c statistic:

$$S_c = \frac{1}{J}\sum_{j=1}^{J}\left[r^* - \frac{1}{J}\sum_{h=1}^{J} r_h^*\right]^2 \tag{8}$$

As Eq. (8) suggests, a small S_c implies the stability of r^* since S_c approaches zero when r^* converges to the average of its own previous values. Thus, according to Eq. (8), r^* should be chosen when S_c approaches zero, and Alessi et al. (2010) proposed a graphical approach to evaluate it.

Our estimates for r^* and S_c are shown over a range of c in Figure 1. They are obtained with $k = 5$ for a set of real effective exchange rates and real interest rates, and we show that there is one common factor in both data. When several stability interval periods exist, we choose the second long interval following the practical guidance of Alessi et al. (2010). Thus Figure 1 seems to suggest that there is one common factor in a set of 78 real effective exchange rates and that of 17 real interest rates. We consider the former as the global movements in real effective exchange rates and the latter as the global interest rate (i.e., $\tilde{R}_t^*$ in Eq. (5)). The global interest rate has been discussed by a number of researchers; for example, the high correlation of real interest rates among advanced countries has been documented by Cumby and Mishkin (1986), Goodwin and Grennes (1994), Gagnon and Unferth (1995), and Monadjemi (1997), and the close relationship between advanced and emerging markets by Chinn and Frankel (1995).

4.2 Estimating global and country-specific factors

Given evidence of the global (common) factor found in the analysis in the previous section, this study uses the factor model in order to calculate the size of this factor in our data. Several researchers have applied the Bayesian approach to the factor model in finance research. For example, Geweke and Zhou (1996) analysed financial portfolios based on the arbitrage pricing theory (APT) in the context of the Bayesian framework, which allows us to estimate a more complicated model than the Maximum Likelihood (ML) approach. We follow their approach to estimate the factor model with $\mathbf{F}_t \sim N(\mathbf{0}, \boldsymbol{I}_k)$ and $\mathbf{e}_t \sim N(\mathbf{0}, \boldsymbol{\Sigma})$ in Eq.(6).

Apart from the number of common factors (r^*), one needs to deal with an identification issue. In particular, the number of parameters estimable has to meet the condition that $n \geq 2r^* + 1$ (Geweke and Zhou (1996)) since the covariance matrix $\mathbf{v}$ is related with $\boldsymbol{\Lambda}$ and $\boldsymbol{\Sigma}$ through $\mathbf{v} = \boldsymbol{\Lambda}'\boldsymbol{\Lambda} + \boldsymbol{\Sigma}$, using the notation used to explain Eq. (6), where $\mathbf{v}$ has $n(n+1)/2$ elements and $\boldsymbol{\Lambda}'\boldsymbol{\Lambda} + \boldsymbol{\Sigma}$ with $nr^* + n$ elements.

Furthermore, given $\boldsymbol{\Lambda}$ is of full rank and the assumption that the first r^* rows of are independent, $\boldsymbol{\Lambda}^{r^*}$ is a lower triangular $r^* \times r^*$ matrix with positive diagonal elements ($\boldsymbol{\Lambda}_{ii} > 0$ where $i = 1, ..., r^*$):

$$\boldsymbol{\Lambda}^{r^*} = \begin{pmatrix} \boldsymbol{\Lambda}_{11} & 0 & \cdots & 0 \\ \boldsymbol{\Lambda}_{21} & \boldsymbol{\Lambda_{22}} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{\Lambda}_{r^*1} & \boldsymbol{\Lambda_{r^*2}} & \cdots & \boldsymbol{\Lambda_{r^*r^*}} \end{pmatrix} \tag{9}$$

We estimate Eq. (6) using the Bayesian approach with a prior distribution; as $\boldsymbol{\Lambda}_{ij}$ is normal with a zero mean for $i \neq j$, the likelihood function becomes

$$p(\mathbf{x}|\mathbf{F}, \boldsymbol{\Lambda}, \boldsymbol{\Sigma}) \propto |\boldsymbol{\Sigma}|^{-T/2} \exp\left(\text{trace}(-0.5\boldsymbol{\Sigma}^{-1}\mathbf{e}'\mathbf{e})\right) \tag{10}$$

This equation will be used to draw observations for parameters ($\boldsymbol{b}_i^*$) in the Gibbs sampling method for $i = 1, ..., r^*$ as:

$$f(\boldsymbol{b}_i^*|\mathbf{F}, \sigma_i) \propto \exp\left(-\frac{1}{2\sigma_i^2}(\boldsymbol{b}_i^* - \hat{\boldsymbol{b}}_i^*)'\mathbf{F}_i'\mathbf{F}_i(\boldsymbol{b}_i^* - \hat{\boldsymbol{b}}_i^*)\right) \tag{11}$$

where $\hat{\boldsymbol{b}}_i^*$ is the OLS estimate ($\boldsymbol{b}_i^* = (\boldsymbol{\Lambda}_{i1}, , \boldsymbol{\Lambda_{ii}})$), and $\mathbf{F}_i$ contains the first r^* elements of $\mathbf{F}$. $\boldsymbol{b}_i^*$ is independently normally distributed. Furthermore, the diagonal elements of $\boldsymbol{\Sigma}$ follow the inverted gamma distribution:

$$f(\sigma_i|\mathbf{F}, \boldsymbol{b}_i^*) \propto \frac{1}{\sigma_i^{v+1}} \exp\left(\frac{-vs_i^2}{2\sigma_i^2}\right) \tag{12}$$

where $s_i^2 = T^{-1}\sum_{t=1}^{T}\mathbf{e}'\mathbf{e}$ and $v = T$. Geweke and Zhou (1996) explained that vs_i^2/σ_i^2 equivalently follows the $\chi^2(T)$ distribution, and when $\mathbf{F}$ and $\mathbf{x}$ are jointly normally distributed, the conditional value of $\mathbf{F}$ and the covariance matrix can be shown as:

$$
\begin{aligned}
E(\mathbf{F}_t|\boldsymbol{\Lambda}, \boldsymbol{\Sigma}, \mathbf{x}_t) &= \boldsymbol{\Lambda}'(\boldsymbol{\Lambda}\boldsymbol{\Lambda}' + \boldsymbol{\Sigma})^{-1}\mathbf{x}_t \\
Cov(\mathbf{F}_t|\boldsymbol{\Lambda}, \boldsymbol{\Sigma}, \mathbf{x}_t) &= \boldsymbol{I} - \boldsymbol{\Lambda}'(\boldsymbol{\Lambda}\boldsymbol{\Lambda}' + \boldsymbol{\Sigma})^{-1}\boldsymbol{\Lambda}
\end{aligned}
\tag{13}
$$

The choice of prior distributions is always a challenge in Bayesian statistics, but those assigned to the parameters here are the standard ones often employed in applied research in economics and finance (Koop (2003)). Our results from the Gibbs sampling method are based on 10,500 replications with 500 burn-in observations, which seem to be adequate to achieve convergence.

One way to show the estimated global and idiosyncratic factors is to present their contribution to the overall variation. Thus, the significance of common and country-specific factors is analysed using the variance decomposition method (Table 5). Our results suggest that a large portion (about 70 to 8 percent) of a variation in real effective exchange rates is attributable to the country-specific elements, and is generally invariant even if a different sample period and country coverage become research targets. Since this is the first attempt to decompose real effective exchange rates, we cannot compare our findings with previous ones. However, one interesting outcome of our study is that advanced countries have experienced a higher proportion of country-specific movements, implying relatively more heterogeneous responses of these countries to the recent financial crises (the Lehman Shock (2008) and the Greek and European sovereign debt crises (2009 onwards)). In contrast, although it is not a significant difference, non-advanced countries tend to follow more common movements after the Lehman Shock.

4.3 Characteristics of latent factors

Next, we analyse the characteristics of the global factor by checking if this factor is persistent and contains a structural shift. If the characteristics are significant, we need to incorporate them in subsequent analyses. First, whether or not the global factor is persistent is examined by evaluating a fractional differencing parameter (d) which can measure persistence in time-series data. This parameter is the focus of unit root tests which often examine if data follow a stationary ($d = 0$) or unit root ($d = 1$) process. Here we allow the possibility that d does not need to be exactly one of these two extreme values. In that case the data can be shown to be stationary if $-1/2 < d < 1/2$, and have a long memory if $0 < d < 1/2$ (e.g. Granger and Joyeux (1980)).

We estimated the size of d for $\mathbf{F}_t$, which is common across countries, by following Geweke and Porter-Hudak (GPH, 1983) and Phillips (1999), who modified the GPH method for nonstationary data by using the log periodogram regression. Our estimates from these two methods are -0.047 [0.263] and -0.180 [0.269] respectively where the numbers in brackets are standard errors. Thus our estimates of d are not statistically significant, and provide evidence against the long memory of the global factors. Therefore, it provides support for the specification of our factor model.

Furthermore, given the number of economic and financial crises during our sample period, we also checked if global and country-specific factors contain a structural shift. In line with this goal, three statistical tests were conducted to analyse the null hypothesis of no structural breaks: the sup$F$, ave$F$, and exp$F$ tests (Andrew (1993), Andrew and Ploberger (1994)). They are popular approaches for detecting a structural shift in stationary data utilizing F statistics obtained from shortened sample periods (discarding the first and last 15 percent of observations). The large size of these statistics becomes evidence of a structural shift in the data. In order to evaluate the statistical hypotheses, p-values are calculated following Hansen (1997).

Our results suggest evidence of structural shifts in country-specific factors of real effective exchange rates (Table 6, Figure 2); in contrast, there is no sign of structural breaks in the common factor. Therefore, it appears that abnormal changes in external competitiveness have been largely attributable to countries own economic responses. This may be surprising because global financial crises have adverse impacts on many countries, and thus one may expect to have structural shifts in the common factor in real effective exchange rates. Again this result implies that heterogeneity in real effective exchange rates results from country-specific factors.

5 Economic explanations of each factor

5.1 Country-specific factors

What would explain the country-specific factors in real effective exchange rates? Based on our findings on the characteristics of data, we analyse this using idiosyncratic components in real interest rates. Since the country-specific factors are supposed to be independent across countries, the mean group (MG) estimate approach which assumes no cross-sectional dependence across countries, is used to understand the relationship between heterogeneity in country-specific real effective exchange rates and interest rates. The MG is useful for obtaining the sensitivity of these two rates while taking into account heterogeneous sensitivities (slopes) among countries (Pesaran and Smith (1995)). We obtain the MG parameter for the panel data by averaging the parameters obtained from individual country analyses. Furthermore, given that there are structural breaks in our data, the specification of countries which have experienced structural breaks contain a dummy variable. This dummy is equal to one after the breakpoint identified by the F test (Figure 2) and to zero otherwise. The countries which did not exhibit a structural break do not contain any dummy.

Table 7 summarises the results from the OLS and MG methods for the purposes of comparison. The parameters of the real interest rates are of the most interest to us and are reported to be negative and statistically significant, consistent with economic theory. While the size and statistical significance of this parameter differ among countries, the negative relationship between country-specific movements in real effective exchange rates and interest rates is confirmed for the majority of countries.

5.2 Global factor

Similarly, we analyse the relationship between the global component in the real effective exchange rates and the world real interest rates. The global factor ($\mathbf{\Lambda}_n\mathbf{F}_t$) differs among countries, and, unlike country-specific factors, the elements in the global factor do not suffer from structural breaks and are expected to be correlated across countries. Therefore, in order to take into account the common time and country-specific effects in the global factor, we examine this relationship using the augmented MG (AMG), which yields consistent estimates in the presence of cross-sectional dependence.

The estimation of the AMG consists of two steps; first, we obtain the time effects by means of the following equation for the global factors of real exchange rates ($\mathbf{x}$):

$$\Delta \mathbf{x}_{nt} = b_n^{'} \Delta \mathbf{z}_{nt} + c_t \Delta \boldsymbol{D}_t + \mathbf{e}_{nt} \tag{14}$$

where $\mathbf{x}_{nt} = \boldsymbol{\Lambda}_n \mathbf{F}_t$ and $\mathbf{z}_{nt}$ is a vector of the global factor of real interest rates. The $\mathbf{D}$ is equal to one for a particular year and to zero otherwise, and this dummy can be considered to capture the common factor in the global factor. The second step involves the estimation of Eq. (15) using the common time effect obtained from Eq. (14):

$$\mathbf{x}_{nt} = b_n^{'} \mathbf{z}_{nt} + c_n \mu_t + \mathbf{e}_{nt} \tag{15}$$

where $\mu_t = \hat{c}_t$. These two steps are estimated by the OLS, and the slope for the panel data can be calculated by $\tilde{b} = N^{-1} \sum_{i=1}^{N} b_i$ (Eberhardt and Bond (2009)).

Table 8 summarises the results from the AMG and confirms in the panel context the positive and significant relationship between the global factors in the real exchange rates and the interest rates. This relationship is consistent with theoretical predictions depicted in Eq. (5), and implies that a rise in the global interest rate (both R^* and the common time effect (Common)) will increase home countries' external competitiveness. An individual country analysis provides somewhat weaker evidence for this relationship because the parameter sign for R^* is negative in four countries but it is the common time effect which influences the global factor of real exchange rates statistically significantly and positively.

6 Conclusion

For a large group of countries, we have analysed if there is any common trend in real effective exchange rates which can be regarded as a proxy for the external competitiveness of countries. By decomposing exchange rates into global and country-specific factors using a Bayesian factor model, we have confirmed that there is a unique trend in these rates. However, the common trend in the exchange rates does not mean that all countries are losing or gaining external competitiveness simultaneously. The majority of movements in real effective exchange rates are found to be idiosyncratic rather than common factors, and this phenomenon is observed especially in advanced countries after the Lehman Shock. These results imply that the external competitiveness of a country is rather heterogeneous, and thus, a country which loses market competitiveness cannot solely blame external factors for the loss.

The results of our further analysis suggest that this common trend can be explained by the global interest rate computed by the factor model, and the country-specific movements by the idiosyncratic movements in interest rate changes. Therefore, the degree to which competitiveness has changed is largely determined by the countries' economic policies. This finding supplements that of Mbaye (2013), who confirmed a productivity channel in economic growth; our results suggest that low real interest rates at home lead to increases in real effective exchange rates that often have a positive relationship with net trade volume, which measures part of general economic activities.

Our findings are in contrast to those of previous studies which have often reported a poor relationship between exchange rates and interest rates (e.g. Edison and Pauls (1993)). With regard to this relationship, recent studies point to the importance of private information, carry trades, investors irrationality, and risk premia, among many others (e.g., Evans and Lyons (2002)). While a direct comparison cannot be made between studies on nominal and real exchange rates, our results which are more consistent with theoretical predictions may be attributable to the consideration of low frequency data, which, in turn, allow us to analyse the trend (rather than volatility) of real exchange rates and the third-country effect, which has often been ignored in previous studies focusing on bilateral exchange rates.

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Table 1: List of countries and data sources

id	Country	Interest rates Market rate	Deposit rate	International trade	id	Country	Interest rates Market rate	Deposit rate	International trade
111	United States ⋆	○		○	328	Grenada			
112	United Kingdom ⋆				336	Guyana			
122	Austria ⋆			○	361	St. Kitts and Nevis			
124	Belgium ⋆				362	St. Lucia			
128	Denmark ⋆			○	364	St. Vincent and the Grenadines			
132	France ⋆				369	Trinidad and Tobago			
134	Germany ⋆			○	419	Bahrain			
136	Italy ⋆			○	423	Cyprus *			
137	Luxembourg ⋆				429	Iran			
142	Norway ⋆			○	456	Saudi Arabia			
144	Sweden ⋆	○		○	548	Malaysia		○	
146	Switzerland ⋆	○			564	Pakistan	○		○
156	Canada ⋆	○		○	566	Philippines	○		○
158	Japan ⋆	○		○	576	Singapore *		○	○
172	Finland ⋆	○			612	Algeria			
174	Greece ⋆				618	Burundi			
176	Iceland ⋆				622	Cameroon			
178	Ireland ⋆	○		○	626	Central African Republic			
181	Malta ⋆				646	Gabon			
182	Portugal ⋆				648	Gambia			
184	Spain ⋆	○		○	652	Ghana			
193	Australia ⋆	○			662	Cote d'Ivoire			
196	New Zealand ⋆				666	Lesotho			
199	South Africa	○		○	676	Malawi			
218	Bolivia				686	Morocco			
223	Brazil			○	694	Nigeria			
228	Chile				724	Sierra Leone			
233	Colombia				742	Togo			
238	Costa Rica				744	Tunisia			
243	Dominican Republic				746	Uganda			
248	Ecuador				754	Zambia			
273	Mexico		○		813	Solomon Islands			○
288	Paraguay				819	Fiji			
298	Uruguay		○		853	Papua New Guinea			
299	Venezuela				862	Samoa			
311	Antigua and Barbuda				924	China, Mainland			
313	Bahamas				944	Hungary		○	
321	Dominica				964	Poland			

Notes: Advanced countries are marked with the asterisk.

Table 2: Basic statistics of changes in real effective exchange rates

Country	ave	std. dev.	Country	ave	std. dev.
United States	-0.155	6.584	Grenada	-0.052	5.254
United Kingdom	-0.079	7.268	Guyana	-6.341	23.622
Austria	0.176	2.352	St. Kitts and Nevis	0.042	4.043
Belgium	-0.318	3.514	St. Lucia	0.050	4.462
Denmark	0.253	3.218	St. Vincent and the Grenadines	-0.307	5.355
France	-0.505	3.185	Trinidad and Tobago	1.112	9.509
Germany	-0.382	3.980	Bahrain	-1.800	7.602
Italy	0.159	4.967	Cyprus	-0.362	3.208
Luxembourg	-0.184	2.155	Iran	-2.620	49.072
Netherlands	-0.142	3.508	Israel	0.294	5.665
Norway	0.040	4.307	Saudi Arabia	-2.495	7.304
Sweden	-1.023	6.547	Malaysia	-1.333	6.924
Switzerland	0.668	4.943	Pakistan	-1.902	6.611
Canada	0.066	6.432	Philippines	-0.615	9.582
Japan	0.172	10.687	Singapore	0.506	4.759
Finland	-0.359	5.461	Algeria	-3.262	13.585
Greece	0.478	3.928	Burundi	-1.364	11.750
Iceland	-0.754	9.467	Cameroon	-0.889	9.364
Ireland	0.236	5.084	Central African Republic	-1.516	10.954
Malta	-0.222	3.535	Gabon	-2.164	10.386
Portugal	0.804	3.785	Gambia	-3.730	10.803
Spain	0.240	4.733	Ghana	-6.941	40.108
Australia	0.275	8.928	Cote d'Ivoire	-0.742	10.876
New Zealand	0.892	8.516	Lesotho	-2.638	17.021
South Africa	-2.039	12.151	Malawi	-3.161	19.247
Bolivia	-0.815	29.583	Morocco	-1.122	3.817
Brazil	0.475	15.928	Nigeria	-2.474	38.498
Chile	-1.434	9.802	Sierra Leone	-2.599	36.069
Colombia	-0.875	10.661	Togo	-1.322	10.839
Costa Rica	-0.707	14.070	Tunisia	-2.470	5.827
Dominican Republic	-1.111	14.358	Uganda	-8.703	33.525
Ecuador	-1.545	15.481	Zambia	-2.106	28.105
Mexico	-0.398	15.487	Solomon Islands	-0.281	11.148
Paraguay	-1.069	11.669	Fiji	-1.262	6.964
Uruguay	0.734	12.341	Papua New Guinea	-0.315	9.044
Venezuela	1.203	20.395	Samoa	-0.157	6.334
Antigua and Barbuda	-0.892	6.594	China, Mainland	-2.439	11.946
Bahamas	-0.011	4.386	Hungary	1.405	6.249
Dominica	-0.466	4.742	Poland	-5.726	46.158

Notes: 'ave' shows the average value of exchange rates.

Table 3: The stationarity of real effective exchange rates and real interest rates

		Real exchange rates		Real interest rates	
		Statistics	p-value	Statistics	p-value
LLC	t	-2.879	0.002	-3.025	0.001
Inverse chi-square (34)	P	165.968	0.000	155.832	0.000
Inverse normal	Z	-9.721	0.000	-8.172	0.000
Inverse logit	L^*	-11.111	0.000	-10.073	0.000
Modified inverse chi-square	P_m	16.003	0.000	14.774	0.000

Notes: the LLC is the panel unit root test developed by Levin, Lin and Chiu (2002), and others by Choi (2001).

Table 4: The relationship between real effective exchange rates and international trades

Lag on exchange rates	Net trade volume	*p*-value	Lead on exchange rates	Net trade volume	*p*-value
-Q12	0.031	0.127	+Q1	0.024	0.238
-Q11	0.037	0.065	+Q2	0.031	0.116
-Q10	0.043	0.031	+Q3	0.033	0.100
-Q9	0.039	0.049	+Q4	0.037	0.068
-Q8	0.037	0.062	+Q5	0.045	0.025
-Q7	0.037	0.064	+Q6	0.053	0.008
-Q6	0.040	0.047	+Q7	0.057	0.004
-Q5	0.035	0.083	+Q8	0.061	0.002
-Q4	0.039	0.054	+Q9	0.070	0.000
-Q3	0.038	0.060	+Q10	0.077	0.000
-Q2	0.032	0.110	+Q11	0.085	0.000
-Q1	0.025	0.205	+Q12	0.092	0.000
-Q0	0.023	0.249			

Notes: The lag on real exchange rates is shown as a 'minus' quarter (Q), and the lead as a 'plus' quarter. Therefore, the contemporaneous relationship between exchange rates and net exports is indicated as '-Q= 0'

Table 5: The variance decomposition of real effective exchange rates

	1981Q1-2014Q		1999Q1-2014Q3		2008:Q3-2014Q3	
A group of countries	**ΛF**	**e**	**ΛF**	**e**	**ΛF**	**e**
All countries	0.228	0.772	0.233	0.767	0.333	0.667
17 countries	0.178	0.822	0.181	0.819	0.304	0.696
Non-advanced countries	0.214	0.786	0.178	0.823	0.400	0.600
Advanced countries	0.257	0.743	0.336	0.664	0.216	0.784

Notes: **ΛF** represents common factors and **e** idiosyncratic factors. '17 countries' are ones which have data on real interest rates.

Table 6: Structural shifts in the common and idiosyncratic factors

	exp$F$	p-value	sup$F$	p-value	ave$F$	p-value
Exchange rates (Common+idiosyncractic)						
United States	0.950	0.205	5.440	0.175	1.115	0.295
Sweden	0.470	0.444	3.478	0.406	0.753	0.452
Switzerland	0.705	0.299	6.504	0.109	0.794	0.430
Canada	2.314	0.036	8.941	0.036	2.604	0.069
Japan	5.765	0.000	16.950	0.001	7.248	0.001
Finland	3.157	0.012	11.444	0.011	2.037	0.114
Ireland	1.094	0.167	5.979	0.138	1.542	0.186
Spain	0.697	0.302	3.084	0.477	1.127	0.291
Australia	2.675	0.023	9.613	0.026	3.565	0.031
South Africa	0.434	0.474	5.009	0.211	0.500	0.621
Mexico	1.857	0.062	10.628	0.016	0.997	0.338
Uruguay	4.765	0.001	14.868	0.002	4.301	0.017
Malaysia	1.837	0.064	6.995	0.087	2.657	0.066
Pakistan	6.480	0.000	17.541	0.001	11.238	0.000
Philippines	3.844	0.004	12.373	0.007	4.667	0.013
Singapore	3.612	0.006	11.285	0.012	3.580	0.031
Hungary	2.903	0.017	10.338	0.019	2.674	0.065
Common factor	0.550	0.386	3.091	0.475	0.956	0.355
Idiosyncratic factor						
Canada	2.525	0.028	9.597	0.026	2.715	0.062
Japan	5.301	0.000	15.606	0.002	6.844	0.001
Finland	2.310	0.036	9.523	0.027	1.753	0.150
Australia	2.889	0.018	10.452	0.018	3.408	0.035
Mexico	1.576	0.088	10.580	0.017	0.739	0.460
Uruguay	3.741	0.005	12.108	0.008	3.561	0.031
Malaysia	2.153	0.044	8.530	0.043	2.493	0.076
Pakistan	13.346	0.000	34.030	0.000	13.108	0.000
Philippines	3.340	0.009	10.897	0.014	4.232	0.018
Singapore	3.726	0.005	11.968	0.009	3.873	0.024
Hungary	5.355	0.000	16.742	0.001	4.338	0.017

Notes: The tests based on Andrew (1993) and Andrews and Ploberger (1994). The test for idiosyncratic factors is conducted for countries who seem to have structural shifts in the overall exchange rates (common+idiosyncratic).

Table 7: OLS and Mean Group (MG) estimation for country-specific factors.

	Coef.	Std Err	p-value		Coef.	Std Err	p-value
OLS				Group-specific			
R	-0.012	0.002	0.000			Australia	
Dummy	0.251	0.051	0.000	R	0.012	0.038	0.743
Constant	0.000	0.021	0.997	Dummy	0.588	0.211	0.005
MG				Constant	-0.275	0.223	0.217
R	-0.032	0.016	0.042			South Africa	
Dummy	0.085	0.086	0.324	R	-0.030	0.020	0.129
Constant	0.036	0.055	0.514	Constant	0.082	0.101	0.417
Group-specific		US				Mexico	
R	0.070	0.016	0.000	R	-0.020	0.009	0.022
Constant	-0.130	0.054	0.015	Constant	0.012	0.076	0.876
		Sweden				Uruguay	
R	-0.010	0.024	0.658	R	-0.007	0.003	0.034
Constant	0.035	0.115	0.760	Dummy	0.759	0.254	0.003
		Switzerland		Constant	-0.483	0.280	0.085
R	-0.099	0.041	0.015			Malaysia	
Constant	0.053	0.081	0.511	R	-0.094	0.034	0.006
		Canada		Constant	0.214	0.109	0.049
R	-0.051	0.032	0.109			Pakistan	
Constant	0.144	0.124	0.244	R	-0.056	0.020	0.005
		Japan		Dummy	0.683	0.133	0.000
R	-0.047	0.079	0.547	Constant	-0.230	0.084	0.006
Dummy	-0.781	0.308	0.011			Philippines	
Constant	0.525	0.299	0.080	R	-0.052	0.016	0.001
		Finland		Dummy	0.360	0.177	0.042
R	-0.066	0.023	0.004	Constant	0.057	0.115	0.619
Constant	0.221	0.111	0.046			Singapore	
		Ireland		R	-0.151	0.030	0.000
R	-0.048	0.017	0.005	Constant	-0.159	0.195	0.414
Constant	0.138	0.086	0.107	R	0.142	0.089	0.110
		Spain				Hungary	
R	-0.038	0.019	0.049	R	0.139	0.023	0.000
Constant	0.102	0.088	0.245	Constant	-0.002	0.074	0.976

Notes: R is country-specific factor of home interest rates, and 'Dummy' is one after the structural break and zero otherwise. The Mean Group (MG) is based on Pesaran and Smith (1995).

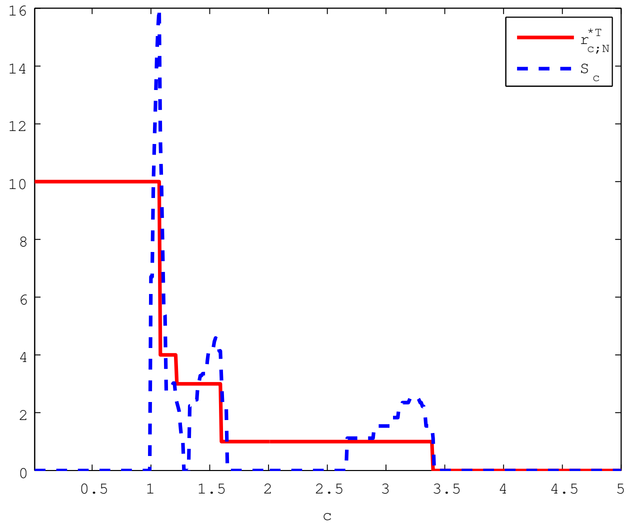
Table 8: Augmented Mean Group (AMG) estimation for common factors

	Coef.	Std.Err.	p-value	Coef.	Std.Err.	p-value
AMG					Australia	
R^*	0.324	0.135	0.017	-0.070	0.119	0.560
Common	1.000	0.224	0.000	1.164	0.231	0.000
Constant	0.474	0.106	0.000	0.552	0.139	0.000
Individual countries		US			South Africa	
R^*	0.064	0.121	0.599	1.091	2.673	0.683
Common	0.244	0.219	0.266	0.693	0.351	0.048
Constant	0.116	0.132	0.380	0.329	0.211	0.119
		Sweden			Mexico	
R^*	0.432	0.186	0.020	0.443	0.465	0.340
Common	1.467	0.269	0.000	1.029	0.360	0.004
Constant	0.696	0.162	0.000	0.488	0.216	0.024
		Switzerland			Uruguay	
R^*	0.714	0.841	0.396	-0.190	0.154	0.218
Common	1.028	0.348	0.003	0.098	0.308	0.750
Constant	0.488	0.209	0.020	0.046	0.185	0.802
		Canada			Malaysia	
R^*	0.126	0.122	0.302	0.200	0.156	0.198
Common	1.315	0.238	0.000	1.756	0.268	0.000
Constant	0.624	0.143	0.000	0.833	0.161	0.000
		Japan			Pakistan	
R^*	-0.048	0.112	0.666	-0.165	0.813	0.839
Common	-1.353	0.216	0.000	2.024	0.302	0.000
Constant	-0.642	0.130	0.000	0.960	0.182	0.000
		Finland			Philippines	
R^*	0.125	0.149	0.404	2.098	0.790	0.008
Common	0.830	0.299	0.005	2.638	0.308	0.000
Constant	0.394	0.180	0.028	1.251	0.185	0.000
		Ireland			Singapore	
R^*	0.194	0.165	0.239	0.273	0.148	0.065
Common	0.618	0.297	0.038	2.221	0.269	0.000
Constant	0.293	0.179	0.101	1.053	0.162	0.000
		Spain			Hungary	
R^*	0.168	0.151	0.267	0.051	0.155	0.740
Common	0.426	0.295	0.148	0.802	0.215	0.000
Constant	0.202	0.177	0.254	0.380	0.129	0.003

Notes: The augmented MG (AMG) is based on Eberhardt and Bond (2009). R^* is the world interest rate and *Common* to μ_t in Eq. (15)

Figure 1: Identifying the number of common factors

a) Real effective exchange rates



b) Real interest rates

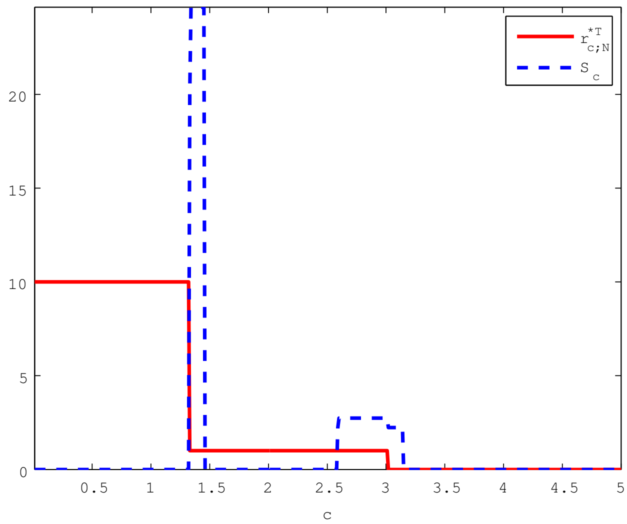


Figure 2: F test for the common and idiosyncratic factors

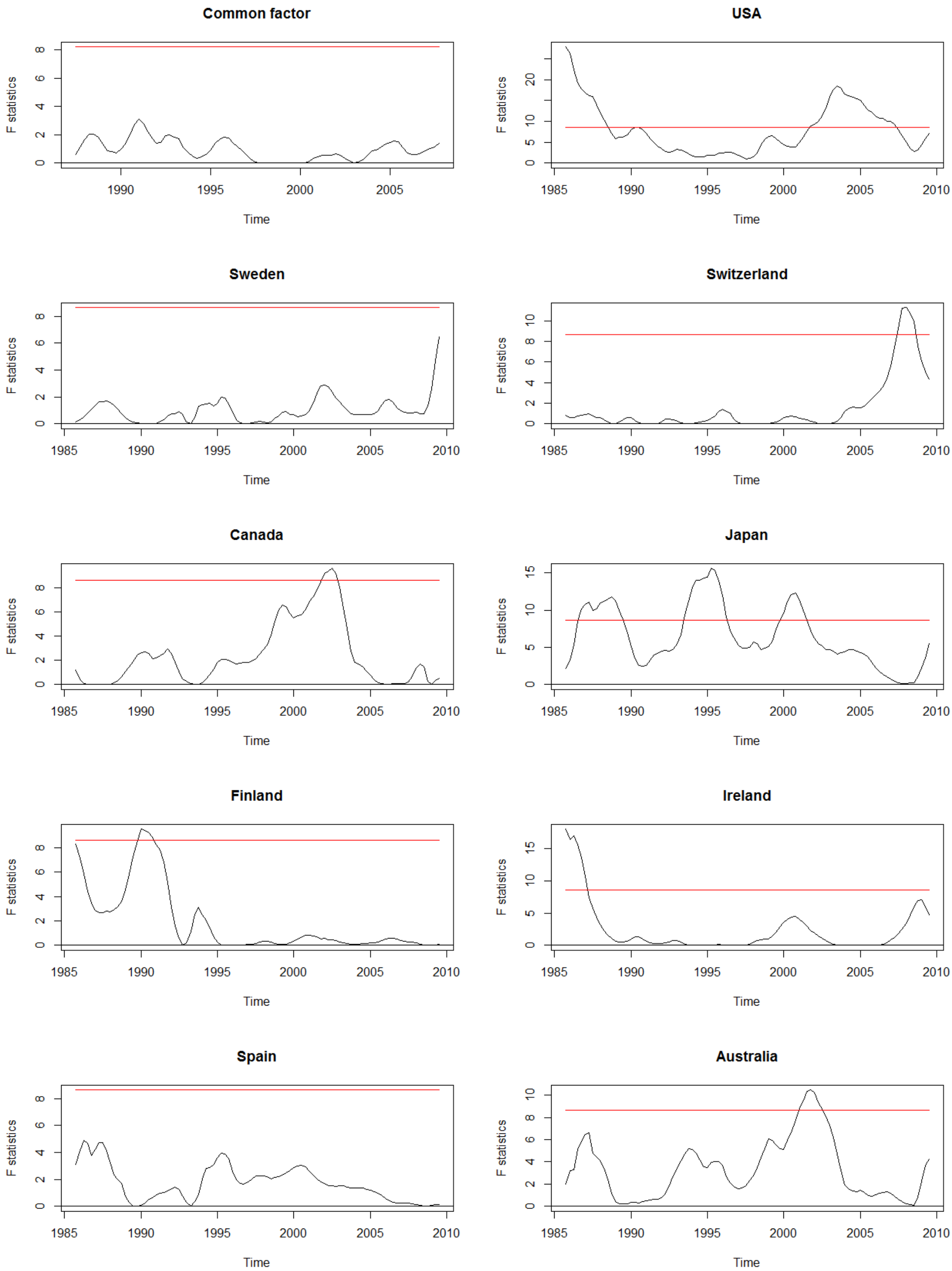


Figure 2: Continued